# GGOS: Depending on Science and a Service for Science

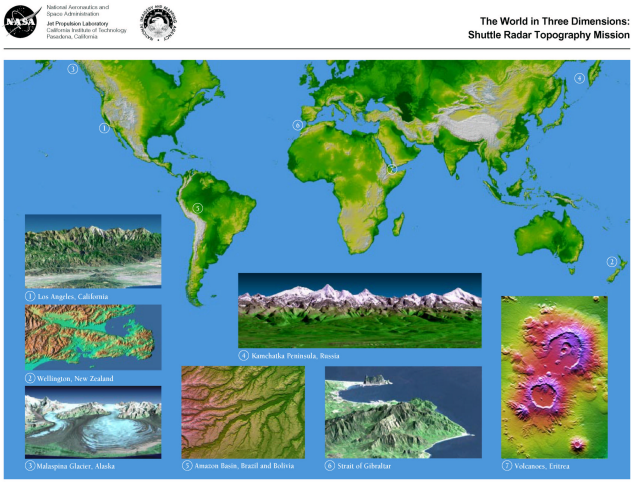
*Richard S. Gross*

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109–8099, USA

Global Geodetic Observing System
Retreat 2008

March 25–28, 2008
Bertinoro, Italy

# The Three Pillars of Geodesy

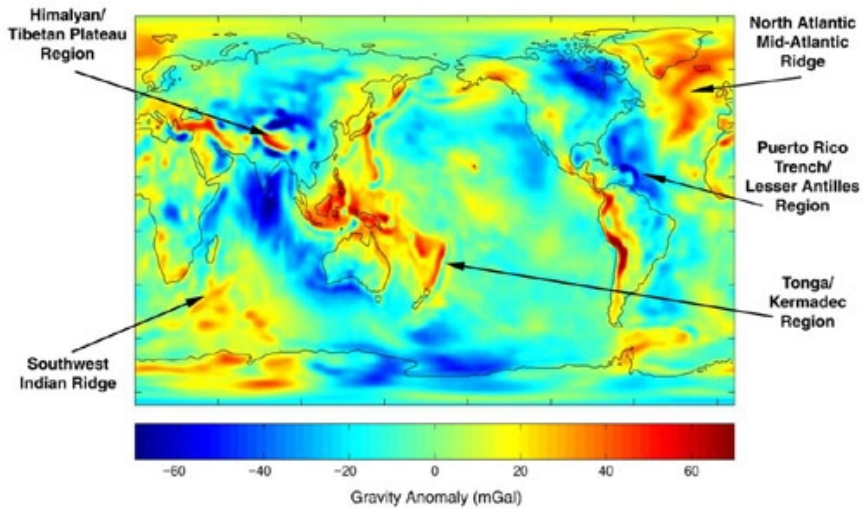



Shape & Deformation

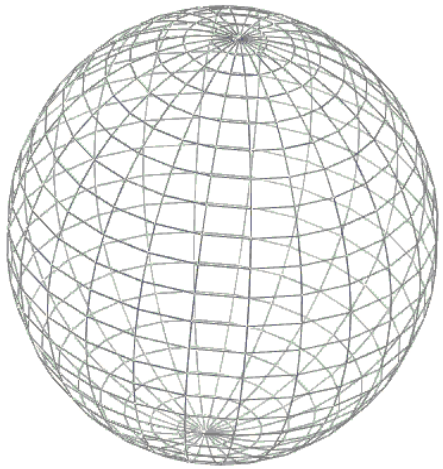
Rotation

QuickTime • and a
YUV420 codec decompressor
are needed to see this picture.

Gravity & Geoid



# The Three Pillars of Geodesy

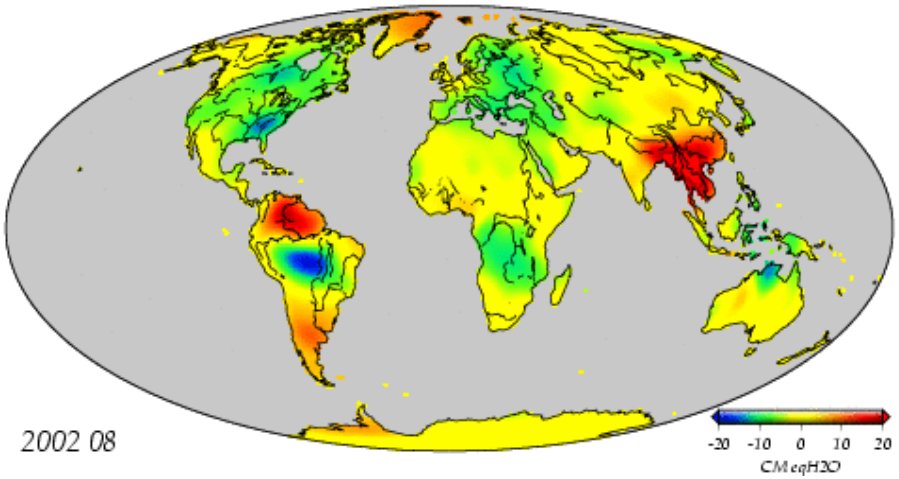


Shape & Deformation

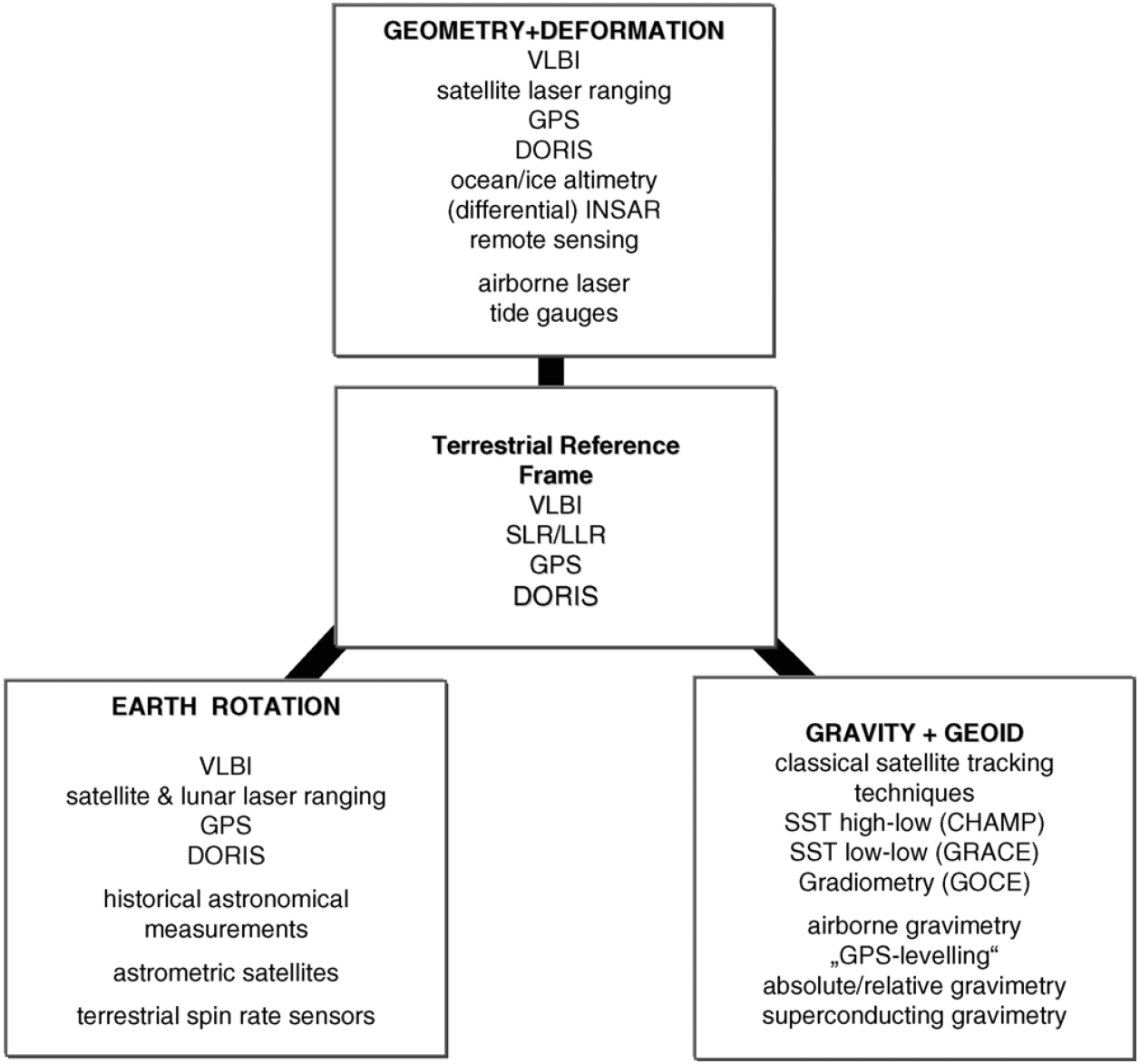
Rotation

QuickTime • and a
YUV420 codec decompressor
are needed to see this picture.

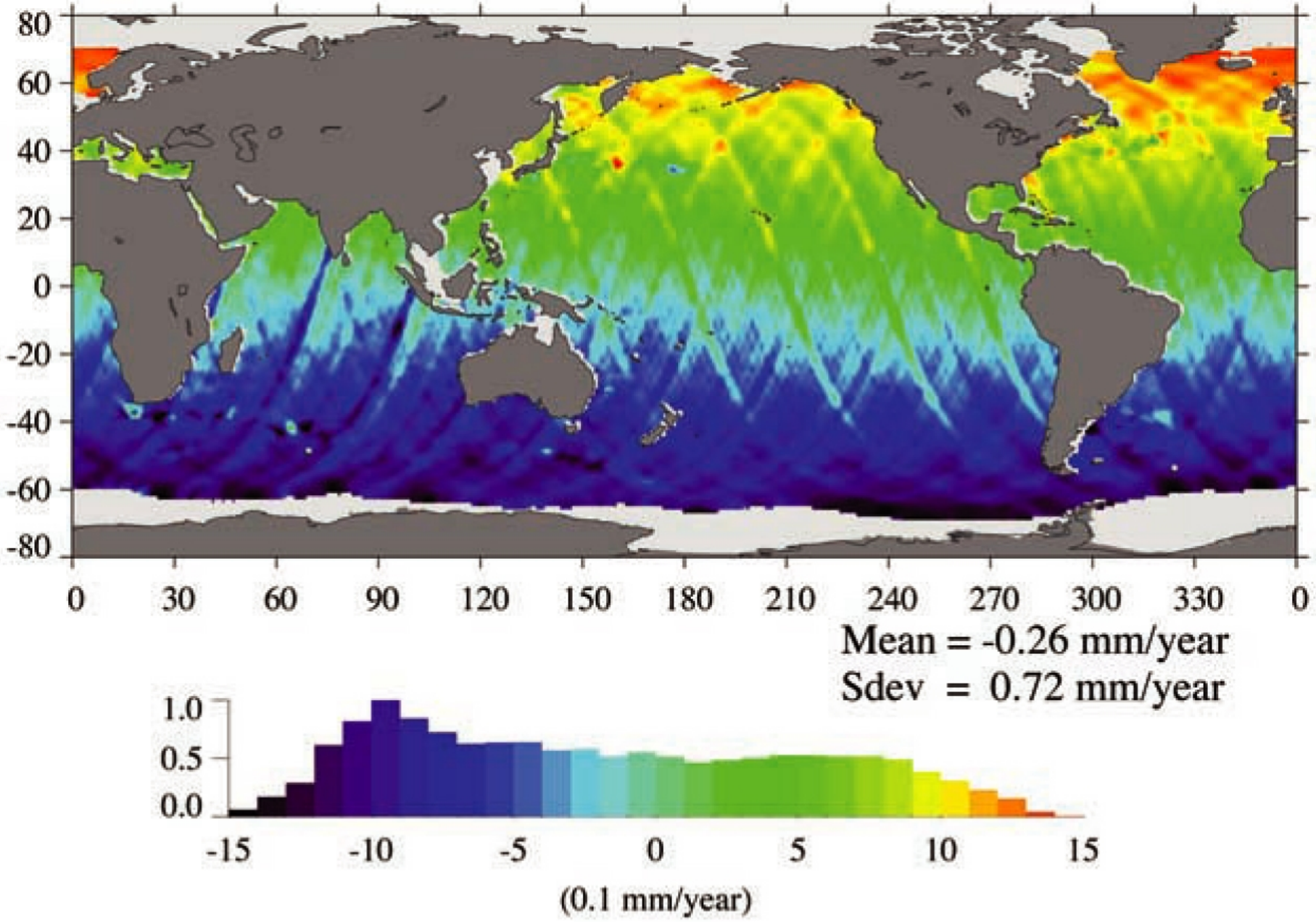
Gravity & Geoid



# Geodetic Observing Systems

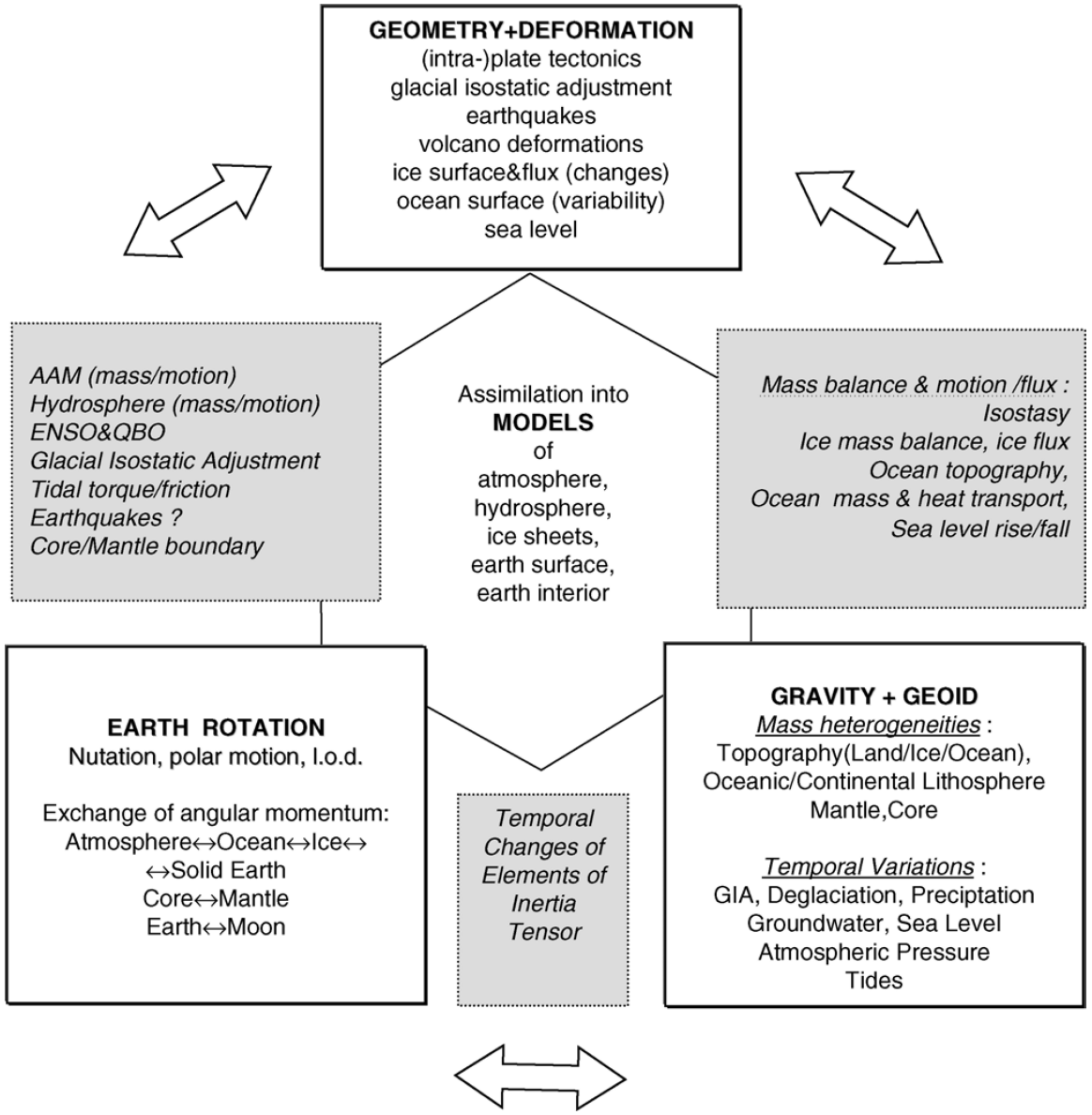



Rummel *et al.* (2005)




Beckley *et al.* (2007)

# Causes of Observed Variations




Rummel *et al.* (2005)

# Mass Load Measurements & Models

(95% significance level of correlation = 0.51)

## (2,0) cosine

| | *Models* | *RL01* | *RL04* | *SLR* | *GPS* | *EOP* |
|---|---|---|---|---|---|---|
| *Models* | 1.0 | 0.62 | 0.70 | 0.94 | 0.88 | 0.57 |
| *RL01* | (37.9) | 1.0 | 0.83 | 0.65 | 0.61 | 0.47 |
| *RL04* | (48.5) | | 1.0 | 0.73 | 0.71 | 0.53 |
| *SLR* | (88.3) | | | 1.0 | 0.87 | 0.68 |
| *GPS* | (6.1) | | | | 1.0 | 0.60 |
| *EOP* | (25.7) | | | | | 1.0 |

greatest correlation between independent measurements

greatest correlation with models

(variance of measurement explained by models in percent)

(greatest variance explained)

## (2,1) cosine

| | *Models* | *RL01* | *RL04* | *SLR* | *GPS* | *EOP* |
|---|---|---|---|---|---|---|
| *Models* | 1.0 | 0.70 | 0.26 | 0.33 | 0.65 | 0.46 |
| *RL01* | (44.4) | 1.0 | 0.40 | 0.52 | 0.49 | 0.37 |
| *RL04* | (–14.4) | | 1.0 | 0.03 | 0.19 | 0.59 |
| *SLR* | (–5.9) | | | 1.0 | –0.03 | 0.07 |
| *GPS* | (38.1) | | | | 1.0 | 0.40 |
| *EOP* | (–14.9) | | | | | 1.0 |

## (2,1) sine

| | *Models* | *RL01* | *RL04* | *SLR* | *GPS* | *EOP* |
|---|---|---|---|---|---|---|
| *Models* | 1.0 | 0.76 | 0.78 | 0.67 | 0.56 | 0.78 |
| *RL01* | (55.9) | 1.0 | 0.81 | 0.56 | 0.71 | 0.83 |
| *RL04* | (58.9) | | 1.0 | 0.53 | 0.61 | 0.81 |
| *SLR* | (42.4) | | | 1.0 | 0.53 | 0.60 |
| *GPS* | (30.2) | | | | 1.0 | 0.56 |
| *EOP* | (61.0) | | | | | 1.0 |

## (2,2) cosine

| | *Models* | *RL01* | *RL04* | *SLR* | *GPS* |
|---|---|---|---|---|---|
| *Models* | 1.0 | 0.40 | 0.74 | 0.26 | 0.59 |
| *RL01* | (16.2) | 1.0 | 0.55 | 0.34 | 0.18 |
| *RL04* | (51.4) | | 1.0 | 0.45 | 0.43 |
| *SLR* | (5.0) | | | 1.0 | –0.09 |
| *GPS* | (15.2) | | | | 1.0 |

## (2,2) sine

| | *Models* | *RL01* | *RL04* | *SLR* | *GPS* |
|---|---|---|---|---|---|
| *Models* | 1.0 | 0.93 | 0.92 | 0.82 | 0.60 |
| *RL01* | (69.2) | 1.0 | 0.95 | 0.83 | 0.61 |
| *RL04* | (75.9) | | 1.0 | 0.85 | 0.64 |
| *SLR* | (61.9) | | | 1.0 | 0.63 |
| *GPS* | (29.1) | | | | 1.0 |

Gross *et al.* (2008)

# GGOS Contributions

- Terrestrial and celestial reference frames
  - Earth orientation parameters
- Precise positioning
  - Monuments on ground
    - Tide gauges
  - Satellites in space
    - Radar and laser altimeters
- Gravity measurements
  - Time variable
    - Ocean-bottom pressure
  - Static
    - Mean ocean circulation
- GNSS reflections

# Unified Observations

- Eliminates inconsistencies
  - Between observations taken by different techniques
    - VLBI, SLR, GPS, DORIS
  - Between EOPs and reference frames
    - IERS Combination Pilot Project
    - Gravity (?)
  - Between measurements taken in different reference frames
    - Example: satellite altimetric measurements of sea surface height
- Strengthens solution
  - Better global distribution of stations
    - VLBI + SLR + GPS + DORIS
  - More measurements
- Requires common standards

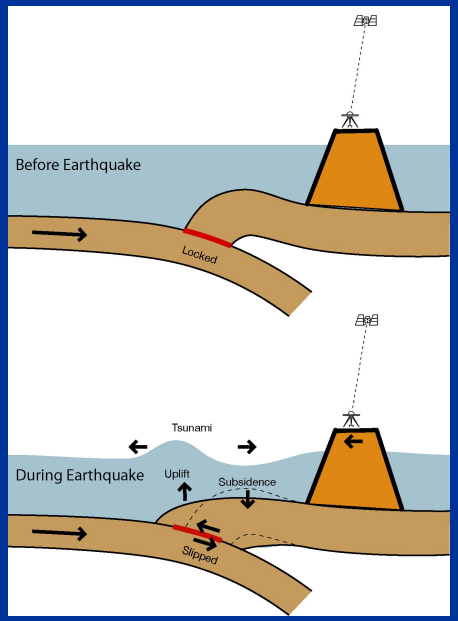
# Unified Models

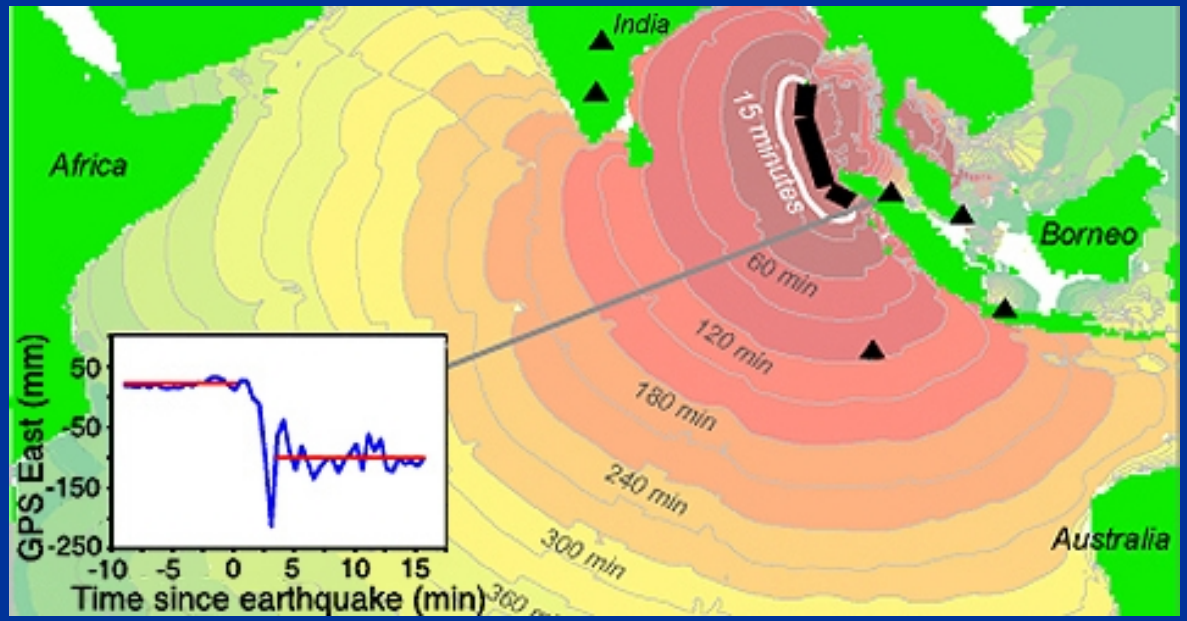
- Changes in observed shape, rotation, and gravity
  - Often have a common cause
    - Examples: atmosphere, oceans, hydrology, earthquakes, GIA
  - But are often modeled separately
    - Example: flat Earth models for earthquake displacements; spherical for rotation
- Develop common models
  - From common shape, rotation, and gravity observations
    - Surface change
    - Mass transport and exchange
    - Angular momentum exchange
- Dynamic Earth theme

# Foundation for a Scientific Vision

- Unify observations
  - Example: IERS Combination Pilot Project
- Unify models
  - Same model used to predict all geodetic observations
- Unify observations with models
  - Assimilate geodetic observations into models
- Dynamic Earth
  - Surface change (natural hazards)
    - Shape and deformation
  - Mass transport and exchange (climate change)
    - Gravity and geoid
  - Angular momentum exchange
    - Earth rotation

# Toward Real-Time GPS for Tsunami Warning Systems and Post-Earthquake Damage Assessment and Emergency Response




**Geoff Blewitt, Corné Kreemer, Bill Hammond, Hans-Peter Plag, Seth Stein, Emile Okal, Yoaz Bar-Sever, Richard Gross, Vindell Hsu, Kenneth Hudnut, Mark Simons, Tony Song, and Frank Webb**

**University of Nevada Reno**
**Northwestern University**
**Jet Propulsion Laboratory**
**NOAA/NWS, USGS, and Caltech**

# GREAT Alert System: Enhance Tsunami Warning System

## Partnerships

### Earth System Models

**Disciplinary Models:**

(1) GPS-inversion model

(2) Seismic inversion model

(3) OGCM-tsunami model

**Coupled Models:**

(1) GPS-Earthquake-Tsunami model

(2) Seismic-Earthquake-Tsunami model

### Earth Observations

**GPS displacements**: NASA-sponsored Global Differential GPS (GDGPS) System

**Seismographs**: NSF-sponsored Global Seismographic Network (GSN)

**Digital Fault Database**: NASA GSFC research products

**RTG software**: NASA/JPL developed Real-Time GIPSY

NASA and Research Partners

**Predictions/Forecasts**

### Information products

Seafloor motions due to earthquakes

Seafloor uplift

Slip direction

Tsunami scale

Earthquake magnitude

**Observations, Parameters & Products**

### Decision Support Systems, Assessments, Management Actions

**Decision Support Tools**

Tsunami source determination

Tsunami scale estimation

**Analyses**

Tsunami potentials

Tsunami travel time

**Decisions / Actions**

(1)Evacuation

(2)Warning scale

(3)Alert and watch

(4)No warning

Partners with Decision Support Tools

### Value & Benefits to Society

*Quantitative and qualitative benefits from improved decisions*

Save lives and property by reliable early warnings

Reduce false alarms by identifying non-tsunami earthquakes

Greater efficiency in avoiding disturbance of business and society

Increase confidence in federal & state agency decision-making and policy

# GREAT Alert System: Enhance Earthquake Damage Assessment

## Partnerships

### Earth System Models

**Disciplinary Models:**

(1) GPS-inversion model

(2) Seismic inversion model

**Coupled Models:**

(1) Shake model

### Earth Observations

**GPS displacements**: NASA-sponsored Global Differential GPS (GDGPS) System

**Seismographs**: NSF-sponsored Global Seismographic Network (GSN)

**Digital Fault Database**: NASA GSFC research products

**RTG software**: NASA/JPL developed Real-Time GIPSY

NASA and Research Partners

**Predictions/Forecasts**

### Information products

Displacement fields

Slip direction

Earthquake magnitude

**Observations, Parameters & Products**

### Decision Support Systems, Assessments, Management Actions

**Decision Support Tools**

Shake maps

**Analyses**

Damage assessment

Situational assessment

**Decisions / Actions**

(1) Prioritize rescue efforts

(2) Plan required emergency resources

(3) Local utilities shutoff

### Value & Benefits to Society

*Quantitative and qualitative benefits from improved decisions*

Save lives and property by prioritizing rescue efforts

More efficient emergency operations and use of resources

Greater efficiency in avoiding disturbance of business and society

Increase confidence in federal & state agency decision-making and policy

Partners with Decision Support Tools